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II Zw 1305.4+2941 AT $z = 0.24$: ANOTHER RICH, RED, COMPACT CLUSTER

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ABSTRACT

Multicolor photographic photometry of a rich Bautz-Morgan type I cluster of galaxies at $z = 0.24$ is used to study its spatial and color distributions. A foreground cluster is recognized from the distribution of galaxies in a two-color diagram that is calibrated with spectroscopic redshifts in the same field. This foreground cluster is statistically removed from the distant cluster counts. No evidence is found for an excess of blue galaxies as defined by Butcher and Oemler. The blue fraction parameter $f_b = -0.01 \pm 0.07$ after corrections for galaxies in the foreground.

Subject headings: galaxies: clustering — galaxies: photometry — galaxies: redshifts

I. INTRODUCTION

The study of distant clusters has received considerable attention over the last decade in part because of the claims by Butcher and Oemler (1978*a*, 1984*a*) that rich, compact clusters of galaxies exhibit increasingly larger fractions of blue galaxies at higher redshifts, especially at redshifts larger than 0.2. Many recent investigations have relied upon spectroscopy (e.g., Dressler and Gunn 1982, 1983; Dressler, Gunn, and Schneider 1985; Butcher and Oemler 1984*b*; Sharples *et al.* 1985; Lavery and Henry 1986) not only to improve the separation of cluster from field, but also to study the spectroscopic properties of cluster members. These spectroscopic studies have uncovered unusual nuclear activity, strong Balmer absorption lines, and active star formation. Photometry of additional clusters has continued in order to determine the extent to which evolution toward bluer colors is a universal phenomenon (Couch and Newell 1985; Couch, Shanks, and Pence 1985; Lefevre *et al.* 1986), especially since at least one cluster, Cl 0016+16 at $z = 0.54$, does not show an excess of blue galaxies (Koo 1981; Ellis *et al.* 1985).

This paper shows that II Zw 1305.4+2941 at $z = 0.24$ is a rich, compact cluster that is very red. Unlike most previous studies that use just two passbands, our addition of a third, ultraviolet band enables us to construct two-color plots that can discriminate galaxies with different redshifts and intrinsic colors (Koo 1985; MacLaren, Ellis, and Couch 1988). This technique has proved crucial in this particular cluster because of the overlap by a foreground cluster (or several groups) of galaxies at $z = 0.125$. A preliminary examination of this cluster using multicolor photometry was made by Koo *et al.* (1984).

II. OBSERVATIONS

The photometric data are from our catalog (Koo *et al.* 1986) covering an $18' \times 18'$ area centered on the cD galaxy in II Zw 1305.4+2941. Prime focus plates of this cluster were obtained with the Mayall telescope of the Kitt Peak National Observatory. All objects brighter than $J = 22.5$ or $F = 21.0$ were included in the catalog, where J refers to our blue band centered at 4650 Å and F refers to our red band centered at 6150 Å. These plates have limits near $J = 24$ and $F = 23$, so the catalog completeness to the above limits should be very reliable. In addition to the two plates in each of these two bands, a single plate centered at 3620 Å (U) and one centered at 8000 Å (N) were also processed to form the final catalog of 494 galaxies and 244 stars. The catalog provides 1950 coordinates accurate to 0\".3, sizes in units of pixels (15 μm = 0\".27) indicating the radii within which their fluxes were measured, J magnitudes, and the three colors $U-J$, $J-F$, and $F-N$. The random photometric errors are ~0.12 mag in J and F at the catalog limit, with larger errors in U and N.

We take advantage of spectroscopic redshifts to calibrate empirically our two-color plots in order to discriminate galaxies at different redshifts. These spectroscopic redshifts are part of a much larger sample being used to study the evolution and clustering properties of faint galaxies (Koo and Kron 1987). The large sample is still being reduced, but 50 redshifts accurate to $\Delta z = 0.01$, more than adequate for our purposes, are available within the area of the photometric catalog. These have been plotted in the $U-J$ versus $J-F$ diagram (Fig. 1*a*), which shows the empirical division line used to separate red-

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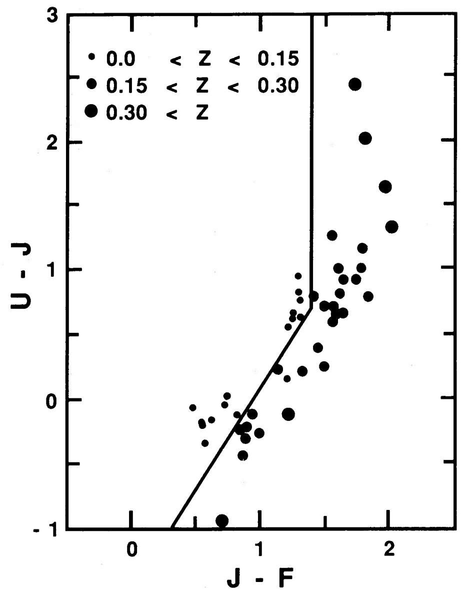

FIG. 1*a*

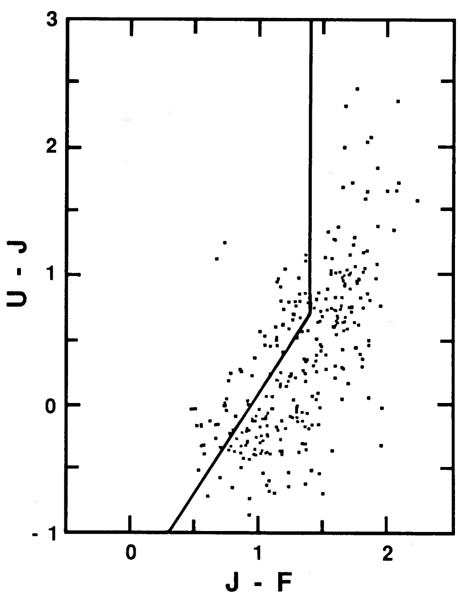

FIG. 1*b*

FIG. 1.—(*a*) Two-color plot, $U-J$ vs. $J-F$, of 50 galaxies in our catalog with spectroscopic redshifts. The line shows the empirical division between nearby galaxies, $z < 0.15$, and those likely to be at the redshift of the cluster, $z = 0.24$. (*b*) Two-color plot, $U-J$ vs. $J-F$, for all galaxies in the catalog brighter than $M_v = -20$ if at $z = 0.24$.

shifts greater than $z = 0.15$. This division is specified by

$$(U-J) - 1.54(J-F) < -1.45 \text{ or } (J-F) > 1.4 . \quad (1)$$

The galaxies with known redshifts did not themselves have any color selection. Moreover, the empirical division line at $z = 0.15$ is consistent with what is expected for normal galaxies according to Bruzual's models (see Koo *et al.* 1984). Figure 1*b* is the $U-J$ versus $J-F$ diagram for all galaxies with $M_v < -20$ if at $z = 0.24$ in order to show that the galaxies with redshifts are representative, and to show that this selection by itself does not automatically reject all blue galaxies. If any peculiar blue galaxies at $z > 0.15$ have been excluded, it is unlikely that they are numerically important, as indicated by a comparison between Figure 1*a* and Figure 1*b*. The galaxies with redshifts tend to be somewhat brighter ($F = 16.3$ to $F = 21.3$, with the median at $F = 19.0$) than the median of the catalog, and are thus expected to have generally smaller photometric errors.

III. ANALYSIS OF CLUSTER PROPERTIES

a) *Photometric Corrections*

i) *Absolute Magnitude*

We follow Butcher and Oemler (1984*a*) by selecting only galaxies brighter than $M_v = -20$ ($H_0 = 50$ km s^{-1} Mpc^{-1} and $q_0 = 0.1$ are adopted throughout). We first determined for $z = 0.24$ the relationship between rest frame M_v and our photographic bands U, J, F, N at the respective rest wavelengths of $\lambda\lambda 2920$, 3750, 4960, and 6450. Although F and N would appear to be the best bands to use, in practice the N band has considerably larger errors, and we rely instead on the J and F bands. We have determined the required transformations from energy distributions of Bruzual (1983). Galaxies will be selected at $z = 0.24$ with $M_v < -20$ if

$$F' < 20.63 , \text{ where } F' = F - 0.23(J-F) . \quad (2)$$

Note that for $J-F > 1.61$ our catalog is not complete to this limit in M_v since F is limited at 21, but this incompleteness will result in a higher proportion of bluer galaxies. Expression (2) assumes no Galactic reddening and no absorption, but the net shift in color would be very small in any case because the colors of the stars in the field are consistent with zero reddening.

Our use of Bruzual energy distributions here and below is little affected by the inclusion of evolutionary effects, because the position of the locus representing different types of galaxies at fixed redshift in a color-color diagram is largely independent of evolution.

ii) *Color-Luminosity Correlation*

These same Bruzual energy distributions also allow a transformation of our $J-F$ colors, which are used to divide between blue and red galaxies after correction for the color-luminosity correlation of ellipticals. Our F band samples between rest frame B and V, and our J band samples very closely rest frame U. On this basis we estimate from Visvanathan and Sandage (1977) that $J-F$ will change by as much as 0.09 mag per mag of visual luminosity. However, the empirical color-magnitude diagrams of Figure 2 suggest that a somewhat shallower slope may actually apply. By adopting a slope of 0.05 and a reference $M_v = -24$ (or $F = 17$) for red galaxies, we conservatively bias the selection toward a larger fraction of blue galaxies. The following definition of the color C' corrects for this color-luminosity correlation:

$$C' = (J-F) + 0.05(F-17) . \quad (3)$$

iii) *Intrinsic Color*

The division between blue and red galaxies was defined by Butcher and Oemler (1984*a*) to be 0.2 mag bluer in rest frame $B-V$ from that of the peak of the color distribution of galaxies. The conservative approach is to adopt an especially red value for this color peak. Sandage (1973) derived for bright cluster ellipticals $\langle B-V \rangle = 0.98$, but his plotted data for the galaxies at lowest redshift indicate $B-V \sim 1.01$, which is consistent with the reddest Bruzual models at age 16 Gyr. We

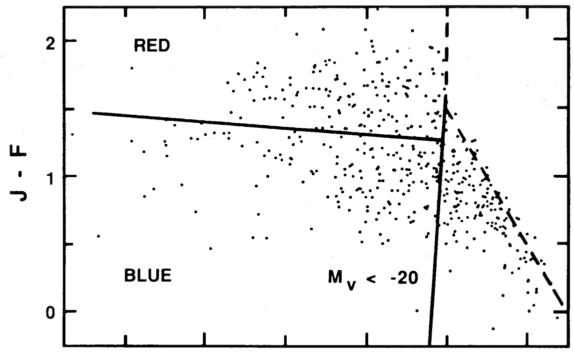

FIG. 2*a*

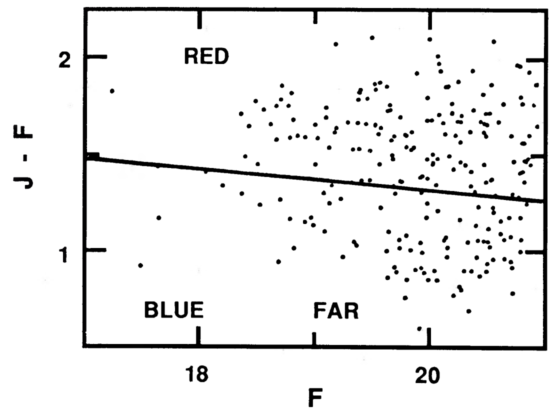

FIG. 2*b*

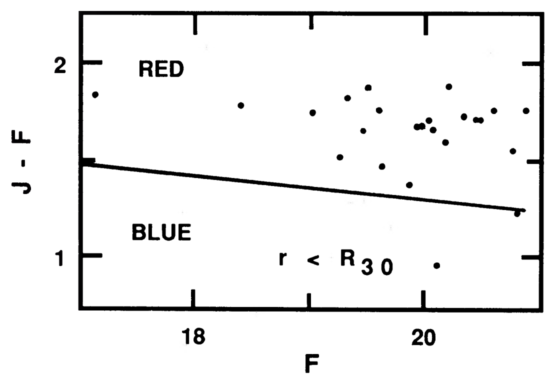

FIG. 2*c*

FIG. 2.—(*a*) Color-magnitude plot, $J-F$ vs. F, all for all galaxies in the catalog. The slanting horizontal line shows the adopted division of galaxies at $z = 0.24$ into red and blue categories. The solid slanting vertical line near $F = 21$ separates galaxies by absolute visual magnitude assuming $z = 0.24$ ($H_0 = 50$ km s^{-1} Mpc^{-1}, $q_0 = 0.1$). The dashed lines show the catalog magnitude completeness limits. (*b*) Color-magnitude plot, $J-F$ vs. F, for all galaxies to the right of the line in Fig. 1*b*, i.e., those galaxies likely to be at $z > 0.15$. (*c*) Same as for Fig. 2*b*, except that only galaxies within the central area (defined as the circle containing 30% of the total cluster population) are plotted.

therefore adopt for the nominal color division $B-V = 0.81$, which is equivalent to $J-F = 1.46$ at $z = 0.24$. Thus

$$C' < 1.46 \text{ for "blue" galaxies} . \qquad (4)$$

This division enhances the fraction of blue galaxies with respect to the procedure of Butcher and Oemler (1984*a*), since the $B-V$ peak of their nearby clusters (Figs. 2 and 3 of Butcher and Oemler 1978*b*) is closer to $B-V = 0.95$ than our adopted $B-V = 1.01$.

iv) *Summary*

Our data can be transformed to yield good estimates of the intrinsic color and intrinsic luminosity for galaxies at $z = 0.24$, including a correction for the color-luminosity correlation. Differences in our selection procedure with respect to Butcher and Oemler (1984*a*) tend to enhance the fraction of blue galaxies. These biases include the incompleteness of the reddest galaxies at $z = 0.24$ with $M_v < -20$, the use of a small correction for the color-luminosity effect, the assumption of no extinction, and the choice of rest frame $B-V = 0.81$ rather than $B-V = 0.75$ as the dividing line between blue and red galaxies. The various divisions in the $J-F$ versus F diagram are shown in Figure 2*a*. The only bias toward a smaller blue fraction would occur if substantial reddening resulted in a shift of blue galaxies into the red class, but the observed red peak at $J-F = 1.78$ is consistent with no such color shift. Figure 2*b* shows what happens when the original sample of Figure 2*a* is restricted to redshifts nominally greater than 0.15 according to the color division of Figure 1.

b) Working Catalogs

Using the above divisions within color, magnitude, and redshift, we have extracted several subcatalogs of the original catalog, as listed in Table 1. The most interesting spatial distributions are perhaps those of galaxies in the subcatalogs NEAR, FAR-BLUE, FAINT, and FAR-RED; these are shown as contour plots in Figure 3*a*, *b*, *c*, *d*, respectively. The NEAR catalog contour plot clearly shows two substantial groupings of galaxies to the east and northeast. The available spectroscopic redshifts (over a field larger than that of Fig. 3) confirm that many galaxies in these groups are indeed at $z < 0.15$, mostly near $z = 0.125$ (Koo *et al.* 1984; Koo and Kron 1987). Both the FAINT and FAR-BLUE distributions are essentially uniform and show no evidence for clustering, especially near the field center. In contrast, the FAR-RED map beautifully defines the rich cluster at $z = 0.24$.

c) Background and Cluster Density Profile

A crucial part of the analysis involves background subtraction. Our field covers a size of 5.4 × 5.4 Mpc (0.3 Mpc per arcmin at $z = 0.24$), which is adequate to define both the cluster and the background. We have assumed that the cD galaxy (catalog no. 337) is at the center of the cluster and have computed the surface density in rings around it. These data were then fitted both by an Emden isothermal sphere profile and King's modified Hubble profile, $\sigma = \sigma_0/[1 + (r/R_c)^2]$, following the procedure of Sarazin (1980). The parameters are the core radius R_c, the central surface density, and the background. The profiles were each fitted using χ^2 minimization to the data in the FAR catalog, which should best represent the distribution of the entire cluster. The results are given in Table 2, where the errors given are the square roots of the diagonal elements of the covariance matrix. The derived parameters are essentially the same for the two profile shapes. As an example, Figure 4 shows the fit for the Emden sphere.

Since the cluster is clearly elongated, we have also obtained profiles in elliptical zones. An image of the galaxy density was constructed by smoothing the galaxy distribution with a Gaussian weighting function with a sigma of 0ʹ.93. Five surface

TABLE 1

CATALOGS

Name	Redshift	Magnitude	Color	Total	N_{30}	$N(r > R_{100})$
ORIG	...	$F < 21$ or $J < 22.5$	...	494	43	195
FAINT	...	$F' > 20.63$	...	190	7	86
M20	...	$F' < 20.63$	...	304	32	109
BLUE	...	$F' < 20.63$	$C' < 1.46$	151	8	94
RED	...	$F' < 20.63$	$C' > 1.46$	153	24	45
NEAR	$z < 0.15$	$F' < 20.63$	...	66	7	25
NEAR-BLUE	$z < 0.15$	$F' < 20.63$	$C' < 1.46$	63	6	24
FAR	$z > 0.15$	$F' < 20.63$	...	238	25	84
FAR-BLUE	$z > 0.15$	$F' < 20.63$	$C' < 1.46$	88	2	40
FAR-RED	$z > 0.15$	$F' < 20.63$	$C' > 1.46$	150	23	44

NOTE.—Catalog area = 325 arcmin^2. Area ($r < R_{30}$) = 9.0 arcmin^2. Area ($r > R_{100}$) = 158 arcmin^2.

density contours at equal intervals in surface density were each fitted by ellipses. The position angle of the major axis was found to be $57° \pm 6°$, and the ratio of minor to major axes was found to be 0.67 ± 0.06, where the errors represent the rms deviation of the measurements from each of the five contours. Densities within elliptical rings specified by these mean values were then used to rederive the profile fits. As expected, the core radii (defined as the square root of the product of the semiaxes) are somewhat smaller than those derived from the circular fits, and again the two profile fitting functions produced similar results (Table 2).

The background level was estimated from the FAR catalog by plotting the surface density in circular annuli centered on the cD (Fig. 5*a*). The cluster cannot be detected beyond a radius of about $R_{100} = 7'.3$, beyond which point the average surface density for this catalog is 0.52 galaxies arcmin^{-2}. Figure 5*b* gives the accumulated growth curve for the FAR catalog, after the subtraction of this background level. This plot is used to determine the growth curve parameters R_{20}, R_{30}, and R_{60}; these are the radii containing respectively 20%, 30%, and 60% of the cluster galaxies. These parameters are determined directly from the data without prior specification of the shape of the profile. The concentration index $C = \log(R_{60}/R_{20}) = 0.55$, so that this cluster indeed qualifies as compact (the Butcher and Oemler criterion is $C > 0.4$).

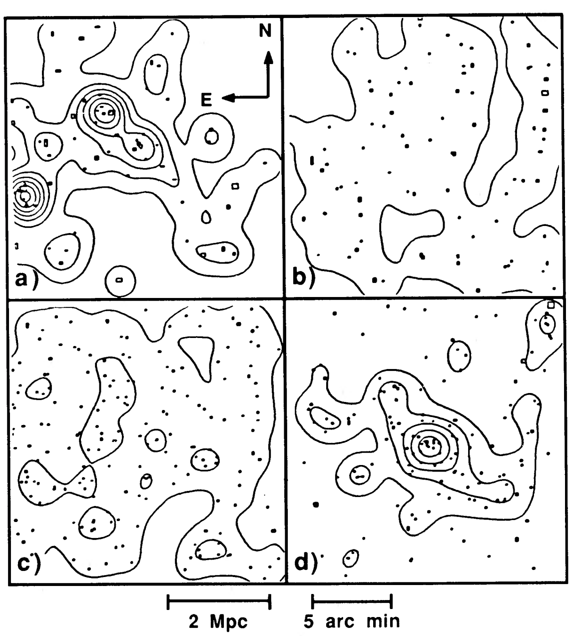

FIG. 3.—(*a*) Iso-surface-density contour map for all galaxies in the NEAR subcatalog, expected to show mainly foreground contamination. The contours are spaced in units of 0.67 σ, where σ is the statistical deviation in the background surface density. The lowest contour is one step below the average background level. (*b*) Same as for Fig. 3*a*, except for the FAR-BLUE catalog. This would be expected to reveal any blue galaxies in the $z = 0.24$ cluster. (*c*) Same as for Fig. 3*a*, except for the FAINT catalog, namely those galaxies fainter than $M_v = -20$ if at $z = 0.24$. (*d*) Same as for Fig. 3*a*, except for the FAR-RED catalog; this shows most of the galaxies in the $z = 0.24$ cluster.

d) cD Galaxy Shape and Orientation

The shape and orientation of the central cD galaxy has been measured at the isophote that is 3.5 mag fainter than the central surface brightness. This isophote has position angle

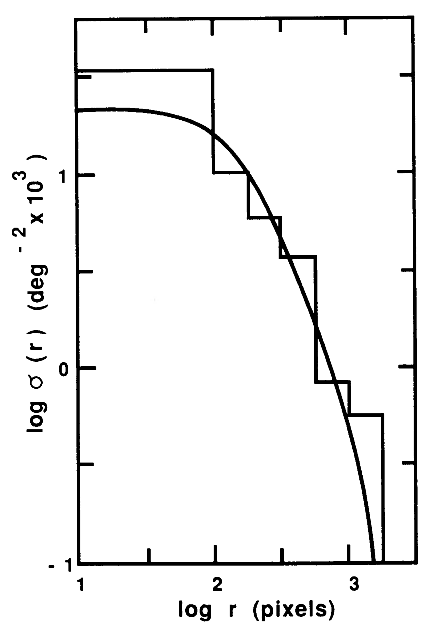

FIG. 4.—Background-subtracted surface density of galaxies vs. radius (in pixels: 1000 pixels = 4'.56). Only galaxies in the FAR subcatalog were used. The smooth curve represents the fit to an isothermal sphere profile, the parameters for which are given in Table 2B.

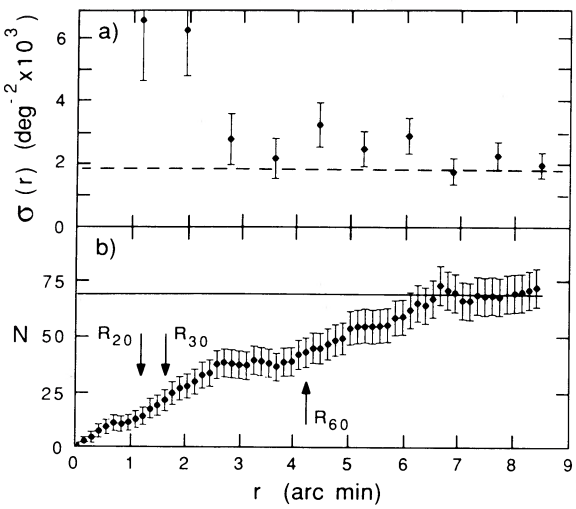

FIG. 5.—(*a*) Surface density averaged in circular annuli from the FAR subcatalog. The error bars represent 1 σ counting errors. The adopted background level is indicated by the horizontal line. (*b*) The integral growth curve from the profile of Fig. 5*a*, after subtraction of the background level.

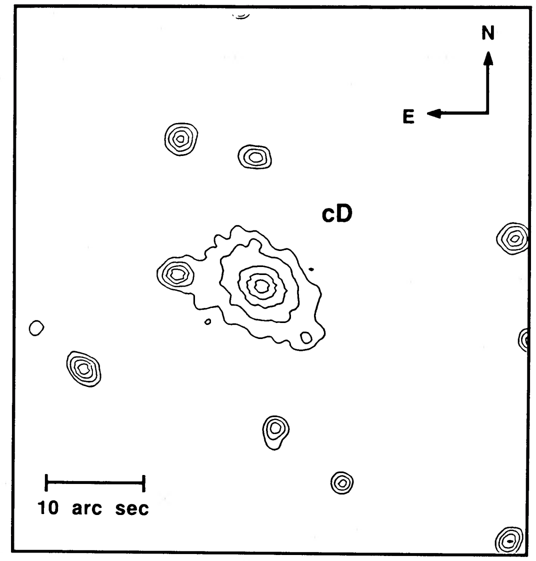

FIG. 6.—Isophotes of galaxies near the cluster center from the *J* plate MPF 1053. The isophotes are spaced at intervals of a factor of 2 in surface brightness, starting from the center of the cD galaxy.

$=61°$ and $b/a = 0.78$, both with errors of about 10%. At this isophote the orientation and axis ratio are within the errors the same as that of the cluster itself. Figure 6 shows that the central isophotes of the cD galaxy are relatively round, which is just due to seeing, and that there is a definite isophote twist toward smaller position angles in the outer regions.

e) Luminosity Function and Richness

We have used the statistically background-subtracted magnitude distribution of galaxies from the FAR catalog to estimate the luminosity function of the cluster galaxies. Our F' magnitude was adopted in order to stay close to rest frame V. The results are shown in Figure 7 for two separate estimates, one using the total sample within R_{100}, and the other from a central elliptical area of $\pi ab = 19.8$ arcmin^2. The two estimates are in reasonable agreement with each other, but they are not of course independent. The luminosity function estimates are compared with that determined for the Coma Cluster by Thompson and Gregory (1980) over an intermediate area: our small and large areas are 1.8 Mpc^2 and 15.1 Mpc^2, compared

TABLE 2A

PROPERTIES OF II Zw 1305.4+2941

Parameter	Values
Position of cD	α(1950) $13^h05^m26^s.27$ δ(1950) $+29°41'46''.7$
Maximum detectable extent	$R_{100} = 7'.3 = 2.2$ Mpc ($H_0 = 50$ km s^{-1} Mpc^{-1}, $q_0 = 0.1$)
Growth curve, circular symmetry	$R_{20} = 1'.19$ $N_{20} = 14.1$
	$R_{30} = 1'.69$ $N_{30} = 21.2$
	$R_{60} = 4'.25$ $N_{60} = 42.3$
Concentration index	$C = \log(R_{60}/R_{20}) = 0.55$
M20, circular f_b	0.17 ± 0.11
M20, elliptical f_b	0.01 ± 0.08
FAR, circular f_b	-0.01 ± 0.07
FAR, elliptical f_b	-0.05 ± 0.08

TABLE 2B

CLUSTER PROFILE

Profile	Central Density (galaxies arcmin^{-2})	R_c (Mpc)	Background (galaxies arcmin^{-2})
Emden, circular	5.97 ± 0.97	0.25 ± 0.02	0.341 ± 0.042
Emden, elliptical	6.51 ± 1.64	0.19 ± 0.02	0.442 ± 0.069
King, circular	5.42 ± 0.83	0.27 ± 0.04	0.465 ± 0.042
King, elliptical	7.03 ± 1.50	0.18 ± 0.03	0.571 ± 0.047

NOTES.—Cluster shape, ellipticity = 0.67 ± 0.06; position angle = $57° \pm 6°$. cD shape, ellipticity = 0.78; position angle 61°. Redshift = 0.24. Bautz-Morgan class = I.

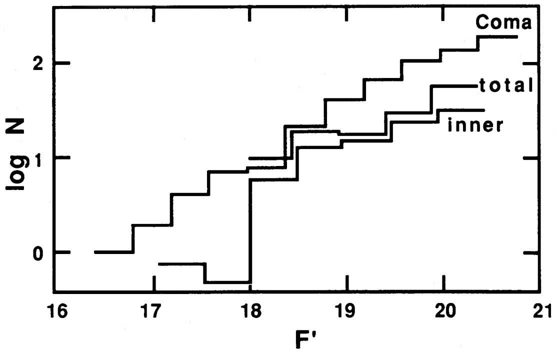

FIG. 7.—Integral luminosity function for II Zw 1305.4+2941 compared to that of Coma from Thompson and Gregory (1980). The two estimates for the luminosity function of II Zw 1305.4+2941 refer to different areas, as described in the text. Values dip below log $N = 0$ because of the statistical correction for the background.

to their 8.0 Mpc^2. II Zw 1305.4+2942 appears to be somewhat less rich than Coma, but not by a very large factor. The shape of the luminosity function for II Zw 1305.4+2941 is not unusual for a Bautz-Morgan type I cluster.

f) Blue Fraction

We have measured the fraction of blue galaxies, f_b, as defined by Butcher and Oemler (1984*a*) for both the circular and the elliptical cases, as well as for the catalogs with and without the redshift selection given by expression (1). For the specific instance of the circular case with redshift selection,

$$f_b = \frac{\text{No. of blue cluster galaxies } (r < R_{30})}{\text{No. all galaxies } (r < R_{30})}$$
$$= \frac{\text{FAR-BLUE } (r < R_{30}) - A * \text{FAR-BLUE } (r > R_{100})}{\text{FAR } (r < R_{30}) - A * \text{FAR } (r > R_{100})}\,, \qquad (5)$$

where $A = 0.057$ is the ratio of areas within R_{30} and outside of $r = R_{100} = 7'.3$. The other required quantities come from Table 1. The errors are estimated from

$$\Delta f_b = \frac{[\text{FAR-BLUE } (r < R_{30}) + A^2 * \text{FAR-BLUE } (r > R_{100})]^{1/2}}{\text{FAR } (r < R_{30}) - A * \text{FAR } (r > R_{100})} \qquad (6)$$

This expression adopts Poissonian errors for the squared errors of the terms in the numerator of equation (5), and the errors due to the denominator were ignored since they are of order $f_b{}^2$. In view of the small numbers involved, there may be better ways to estimate the errors. Equation (6) is intended to give an error estimate that is comparable to that of Butcher and Oemler (1984*a*).

The various determinations of f_b are given in Table 2A. The entry $f_b = 0.17 \pm 0.11$ for the circular case without the redshift selection is known to be an overestimate. According to Table 1 there are 32 galaxies within R_{30}, and eight of these are blue. However, our spectroscopy shows that of the two blue galaxies observed within R_{30}, both are at $z = 0.125$. Of the 24 red galaxies, seven have been observed spectroscopically, and all are at $z = 0.24$. If the six blue galaxies not yet spectroscopically observed are all considered to be candidate members, then $f_b = 0.10 \pm 0.10$, but this is also very likely an overestimate, since Figure 2*c* shows that only two are apparent members based on the color criterion of expression (1).

Table 2A also shows a large difference between the elliptical and circular cases for the M20 catalog. We have investigated this by plotting, for the elliptical case and the M20 catalog, the value of f_b as computed within successive values of $(ab)^{1/2}$. Figure 8 shows a red center, a sharp increase from 1′ to 2′, and a gradually rising value at larger radii, reaching $f_b \sim 0.17$ at R_{100}. For the elliptical case the value for R_{30} corresponds approximately to 1'.15 (about 2 core radii), yielding $f_b = 0.01$ as in Table 2A. Figure 8 shows, however, that f_b is highly sensitive to the value chosen for $(ab)^{1/2}$ in this range of radius. Evidently the spatial and color distributions are such that when R_{30} is calculated with circular symmetry assumed, the result is a higher f_b because of the high sensitivity of f_b to the distribution of galaxies in the cluster.

Histograms of galaxy colors after background subtraction for several radial zones are shown in Figure 9. Within R_{30} there is essentially a pure red peak, nearly free of any blue galaxies. As remarked earlier, the red peak is at the expected color $J - F \sim C' = 1.78$. Beyond R_{30} the histograms show an increasingly larger fraction of blue galaxies, a conclusion consistent with results for other distant clusters (Butcher and Oemler 1984*a*; Thompson 1986).

IV. DISCUSSION

We have made a multicolor photometric study of a rich concentrated Bautz-Morgan type I cluster at moderate redshift. The cluster is apparently typical of its class; for example, the central cD galaxy is both an X-ray source and a radio source (Katgert, Thuan, and Windhorst 1983), and it is flattened with its elongation and orientation similar to that of the cluster itself. Our main goal has been to investigate the color distribution of the cluster-core galaxies. A sample of 50 spectroscopic redshifts within the field of nearly 500 galaxies provides the capability for two-color plots to segregate likely cluster members from galaxies with redshifts less than 0.15. We have adopted the prescription for defining blue galaxies of Butcher and Oemler (1984*a*); slight differences in our procedure bias the result toward a larger blue fraction. Without the correction for the foreground enabled by the multicolor photometry, we derive $f_b = 0.17 \pm 0.11$, a value consistent with an average $f_b \approx 0.12$ at $z \approx 0.25$, compared to the local value $f_b \approx 0.03$. However, either a correction for the foreground gal-

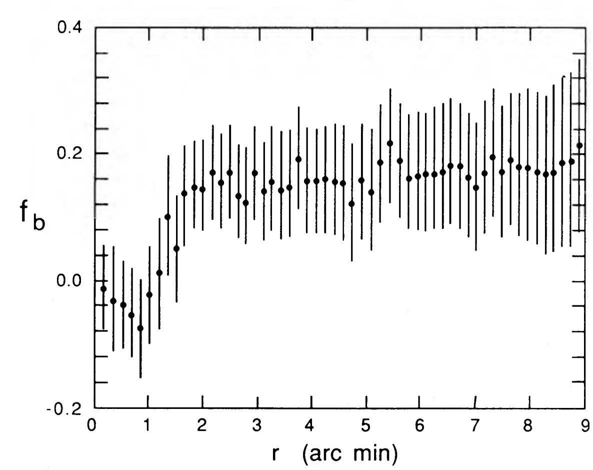

FIG. 8.—Fraction of blue galaxies f_b as a function of radius [$r = (ab)^{1/2}$] in the elliptical case, M20 catalog.

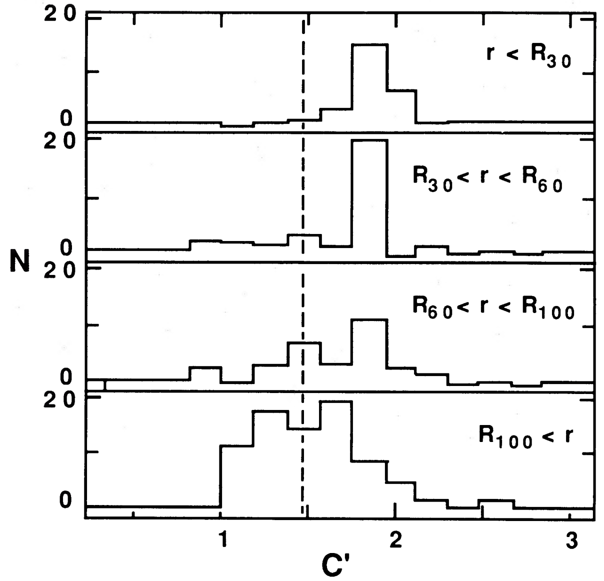

FIG. 9.—Color histograms of galaxies in the FAR subcatalog after background subtraction, in various radial zones. The outermost zone defines the background that was subtracted from the others, after scaling by the ratio of the areas. The vertical dashed line $C' = 1.46$ divides nominally blue from nominally red galaxies.

axies or for the ellipticity of the cluster results in $f_b \approx 0.00 \pm 0.08$; corrections for both yield $f_b = -0.05$ (Table 2A).

We conclude that II Zw 1305.4+2941 has at the 2 σ level no excess of blue galaxies. This result supports the picture in which distant clusters with similar richness and compactness exhibit a wide range of intrinsic color distribution, whereas local counterparts are much more homogeneous in their colors (Butcher and Oemler 1984*a*). The most distant cluster of the entire Butcher and Oemler (1984*a*) sample, Cl 0016+16, shows no excess of blue galaxies (Koo 1981), and there are other examples with $f_b < 0.05$ and $z > 0.2$, such as A2397 and A2645.

The pro-evolution view is increasingly gaining acceptance because the results of spectroscopic surveys (see Dressler 1987; Couch and Sharples 1987; and references therein) almost unanimously claim confirmation of the high blue fractions found in the photometric studies. These investigations also suggest the presence of larger numbers of "active" galaxies or the "E+A" galaxies that may result from a prior burst of star formation.

In the following discussion we take a more cautious and skeptical stance regarding evidence that the cores of distant clusters are undergoing dramatic evolution. This contrary position is based on the problems associated with the selection of the clusters and the definition of the baseline no-evolution case, and with problems with the interpretation of the photometric and spectroscopic data.

Selection of distant clusters remains a poorly understood process, largely because we lack simulations that include all of the relevant aspects (but see Lucey 1983; Chokshi 1986; Chincarini 1988). An appropriate simulation should accurately account for the complex distribution of environments, from field and groups to clusters and superclusters, over a wide interval of redshift. The simulation may also need to include any of the observables used to gauge the amount of evolution: distributions in luminosity, morphology, color, surface brightness, stellar absorption features, emission lines, features associated with active nuclei, nearest neighbor distance, etc. It may also be necessary to consider radio and X-ray properties of the clusters, since in some cases these may govern the original cluster recognition or its selection for further study. Another complication arises in spectroscopic work where line strengths need to be determined as a function of the fractional area of the projected slit.

Since clusters evolve dynamically, comparing high-redshift counterparts to present-day clusters is correspondingly difficult. It is easy to imagine that the clocks which control the observable properties of clusters are neither particularly precise nor well-synchronized, so the evolutionary effects observed in samples of clusters could be small even if any individual cluster can experience an epoch of relatively sudden change. So far, distant clusters have been chosen mainly on the basis of being very rich and compact. For a fixed richness and concentration, a cluster at high redshift will have lower contrast (at least in the optical band) with respect to the projected field. On this basis one might imagine that the distant clusters would be observed to have more red galaxies, since the selection is toward denser systems, which are known locally to have more E and S0 galaxies. On the other hand, if the more distant clusters are often selected because of overlaps with other structures, then the opposite effect of finding more blue galaxies at higher redshifts would be expected.

The field background consists very predominantly of blue galaxies, and thus an intrinsically sharp red peak in the color distribution of galaxies in a cluster can easily be blurred by small errors in assigning cluster membership. Since there is a strong radial increase in the fraction of blue galaxies, a small error in the adopted 30th percentile radius, R_{30}, can introduce an artificially high blue fraction. As discussed in connection with Figure 8, II Zw 1305.4+2941 is illustrative in this regard. Another example comes from Iannicola *et al.* (1987), who measured $f_b = 0.18 \pm 0.06$ for A777, as opposed to $f_b = 0.05 \pm 0.08$ as measured by Butcher and Oemler (1984*a*). They attribute this result to differences in the actual samples of galaxies and differences in treating the projected field galaxies; in any case the point is that the value of f_b is sensitive to the analysis procedure (cf. Table 2A of this paper).

Galaxy membership in the cluster core remains a problem even with accurate redshifts. The high velocity dispersion of rich clusters may encompass hundreds of cubic Mpc on the sky. Galaxies from the outer parts of the cluster, or beyond, may thus be significant contaminants, especially if the cluster was originally selected because its apparent richness was enhanced by an associated supercluster (Koo 1988), or if noncluster-core galaxies were intrinsically different in the past (Ellis 1987; Koo and Kron 1987).

In summary, this work has added only one distant cluster at moderate redshift which has no excess of blue galaxies; by itself it cannot pose a serious threat to the increasing evidence for evolution in high-redshift clusters. The ease, however, with which this cluster could have fitted into the evolution picture had our data been less extensive is a concern, and serves as a warning that more attention be paid to problems in the selection and analysis of clusters before we can be confident in our understanding of cluster evolution.

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